NUMI BPM Readout

Craig Drennan
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I. Introduction

There are two different styles of BPM's for which readout instrumentation is being developed. The first is referred to as the "standard beam transport" BPM's and the second is the "targeting" BPM's. The two differ in size, sensitivity and the required functional accuracy of their readout. Both BPM styles use diagonally cut circular cross-section electrodes which are typically chosen for the more linear response to beam displacement.

I.1 NUMI Design Parameters

The range of NUMI beam intensities used for design purposes are

4e13 protons / 8.0 us ⇔ 9.5e10 ppb (5 batches, 84 bunches / batch)
6e10 protons / 0.188 us ⇔ 6e9 ppb (Beam tuning)*

* We expect to operate at a reduced position accuracy specification at the lowest beam intensity.

Table I.1.1 The Standard NUMI BPM's parameters:

Electrode radius, b.	2 inches
Sensitivity conversion factor, Sx.	4.02 mm/dB (0.249 dB/mm)
Sum/Difference conversion	70.113*(Vr - Vl)/(Vr + Vl)
Output signal amplitude scale factor	0.47 Vpk / 1e10 ppb -- centered 0.61 Vpk / 1e10 ppb -- 20 mm nearer than center 0.34 Vpk / 1e10 ppb -- 20 mm further than center
Maximum expected output signal amplitude at 9.5e10 ppb and 20 mm nearer than center	9.5e10 * 0.61 Vpk / 1e10 ppb = 5.80 Vpk 5.80 Vpk = 4.10 Vrms = +25.3 dBm

Table I.1.2 The Standard NUMI BPM's readout specification:

Desired maximum position error.	0.2 mm rms within +/- 20 mm for beam intensities from 3e10 ppb to 9.5e10 ppb
Beam position range about center.	+/- 20 mm
Beam intensity range.	9.5e10 ppb to 3e10 ppb. (down to 6e9 with reduced position accuracy, and / or change of input gain)
Measurement Accuracy.	0.4%
Available dynamic range given 11 bit digitization 0.4% accuracy.	assuming a 0 to 5 V input range: 5 V / (2^11 bits) / 0.004 = 0.610 V 20 Log (4.62 / 0.610) = 17.5 dB
Dynamic range attributed to +/- 20 mm change in beam position.	20 Log(0.614 / 0.342) = 5.08 dB
Dynamic range available for changes in beam intensity	17.5 dB - 5.08 dB = 12.4 dB = 20 Log (9.5e10 ppb / 2.3e10 ppb)
Synchronous Demodulator: Input signal amplitude range (42 dB attenuation between BPM and input).	-17.0 dBm to -30.5 dBm 31.6 mV RMS to 6.67 mV RMS 44.7 mVpk to 9.44 mVpk
Sub-Nyquist FFT Direct Digitization: Input signal amplitude range (2 dB attenuation between BPM and input).	+23.3 dBm to + 5.80 dBm 3.27 V RMS to 0.436 V RMS 4.62 Vpk to 0.617 Vpk

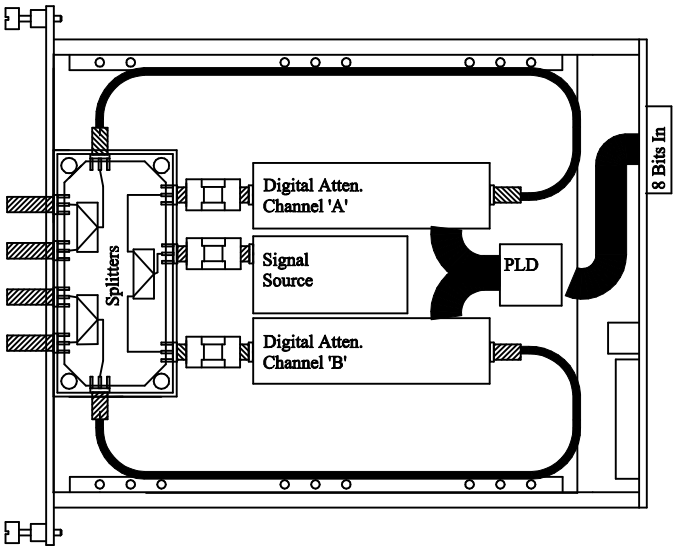
Table I.1.3 The Targeting NUMI BPM's parameters:

Electrode radius, b.	1.06 inches
Sensitivity conversion factor, Sx.	1.72 mm/dB (0.58 dB/mm)
Sum/Difference conversion	30.842 *(Vr - Vl) / (Vr + Vl)
Output signal amplitude scale factor	0.444 Vpk / 1e10 ppb -- centered 0.530 Vpk / 1e10 ppb -- 6 mm nearer than center 0.358Vpk / 1e10 ppb -- -6 mm further than center
Maximum expected output signal amplitude at 9.5e10 ppb and 6 mm nearer than center..	9.5e10 * 0.530 Vpk / 1e10 ppb = 5.04 Vpk 5.04 Vpk = 3.56 Vrms = +24.0 dBm

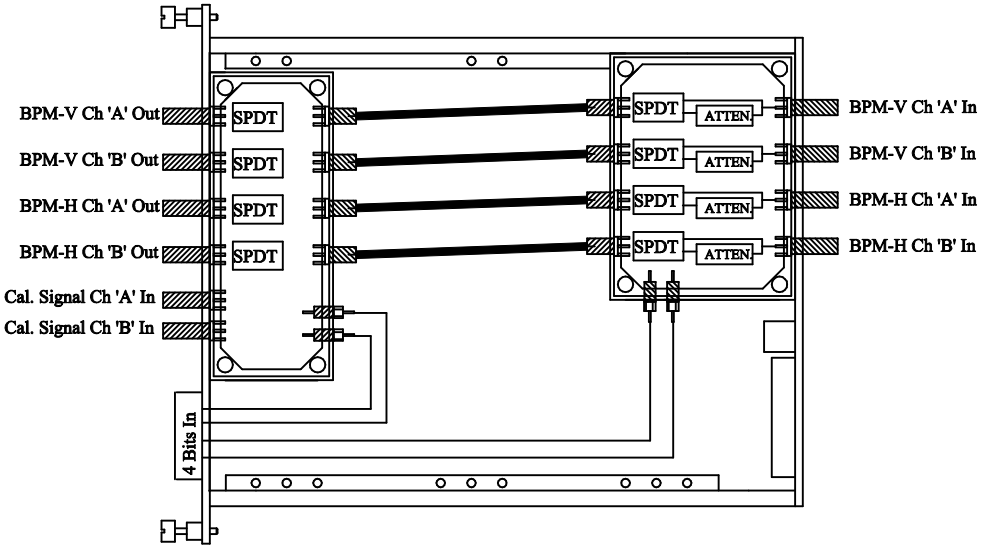
Table I.1.4 The Targeting NUMI BPM's readout specification:

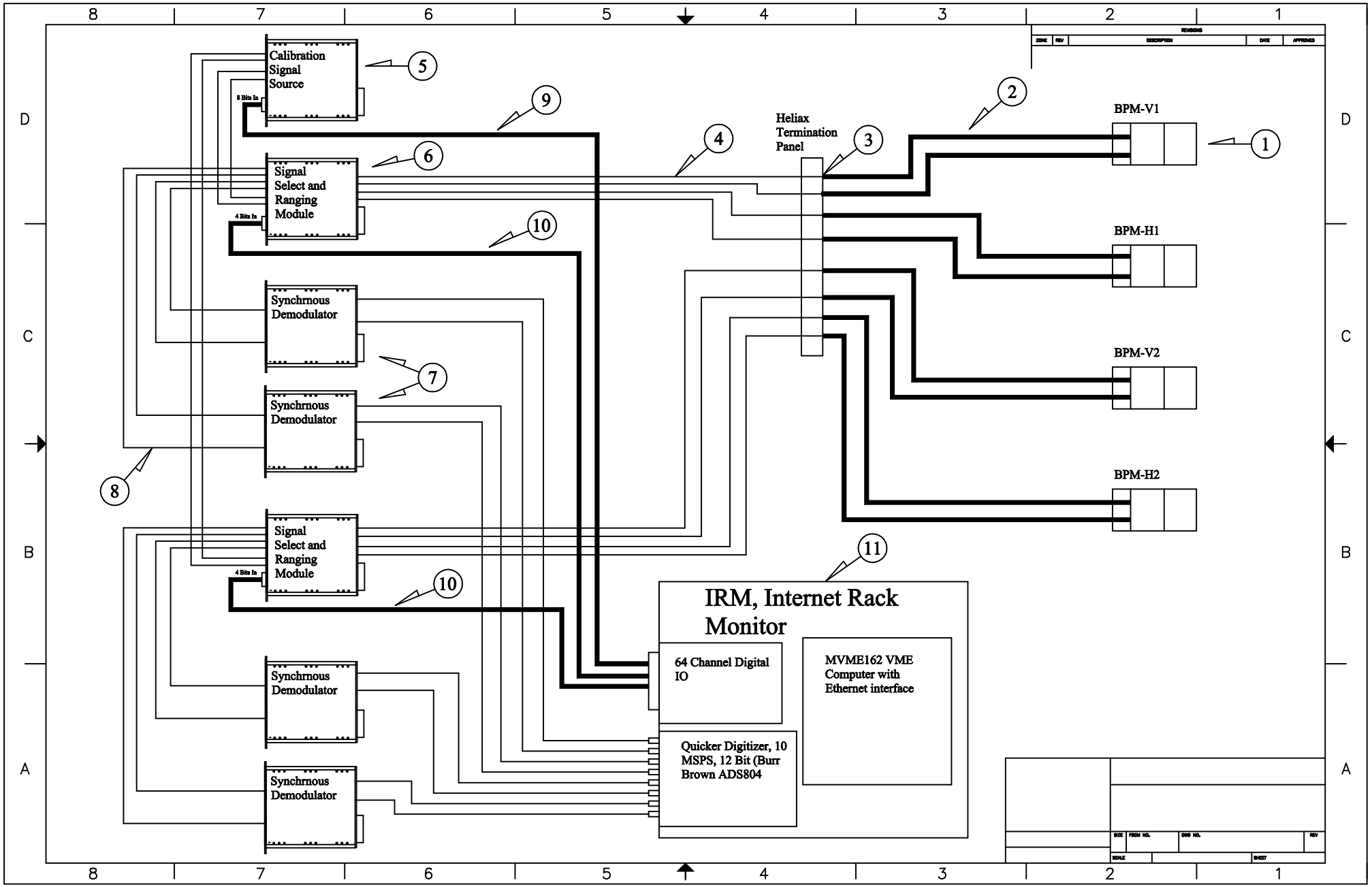
Desired maximum position error.	0.05 mm rms within +/- 6 mm for beam intensities from 3e10 ppb to 9.5e10 ppb
Beam position range about center.	+/- 6 mm
Beam intensity range.	9.5e10 ppb to 3e10 ppb. (down to 6e9 with reduced position accuracy, and or change of input gain)
Measurement Accuracy.	0.23%
Available dynamic range given 11 bit digitization 0.23% accuracy.	assuming a 0 to 5 V input range: 5 V / (2^11 bits) / 0.0023 = 1.06 V 20 Log (5.00 / 1.06) = 13.5 dB
Dynamic range attributed to +/- 6 mm change in beam position.	20 Log(0.530 / 0.358) = 3.41 dB
Dynamic range available for changes in beam intensity	13.5 dB - 3.41 dB = 10.1 dB = 20 Log (9.5e10 ppb / 2.97e10 ppb)
Synchronous Demodulator: Input signal amplitude range (41 dB attenuation between BPM and input).	-17.0 dBm to -30.5 dBm 31.6 mV RMS to 6.67 mV RMS 44.7 mVpk to 9.44 mVpk
Sub-Nyquist FFT Direct Digitization: Input signal amplitude range	+24.0 dBm to + 10.5 dBm 3.56 V RMS to 0.749 V RMS 5.03 Vpk to 1.06 Vpk (may need to adjust the input range of the ADC to adapt for signal attenuation between BPM and input to the electronics).

Calibration Signal Source



Signal Select and Ranging Module




Calibration Signal Source
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Signal Select and Ranging Module
4 Bits In
Synchrnous Demodulator
Synchrnous Demodulator
Signal Select and Ranging Module
4 Bits In
Synchrnous Demodulator
Synchrnous Demodulator
Heliax Termination Panel
BPM-V1
BPM-H1
BPM-V2
BPM-H2
IRM, Internet Rack Monitor
64 Channel Digital IO
MVME162 VME Computer with Ethernet interface
Quicker Digitizer, 10 MSPS, 12 Bit (Burr Brown ADS804
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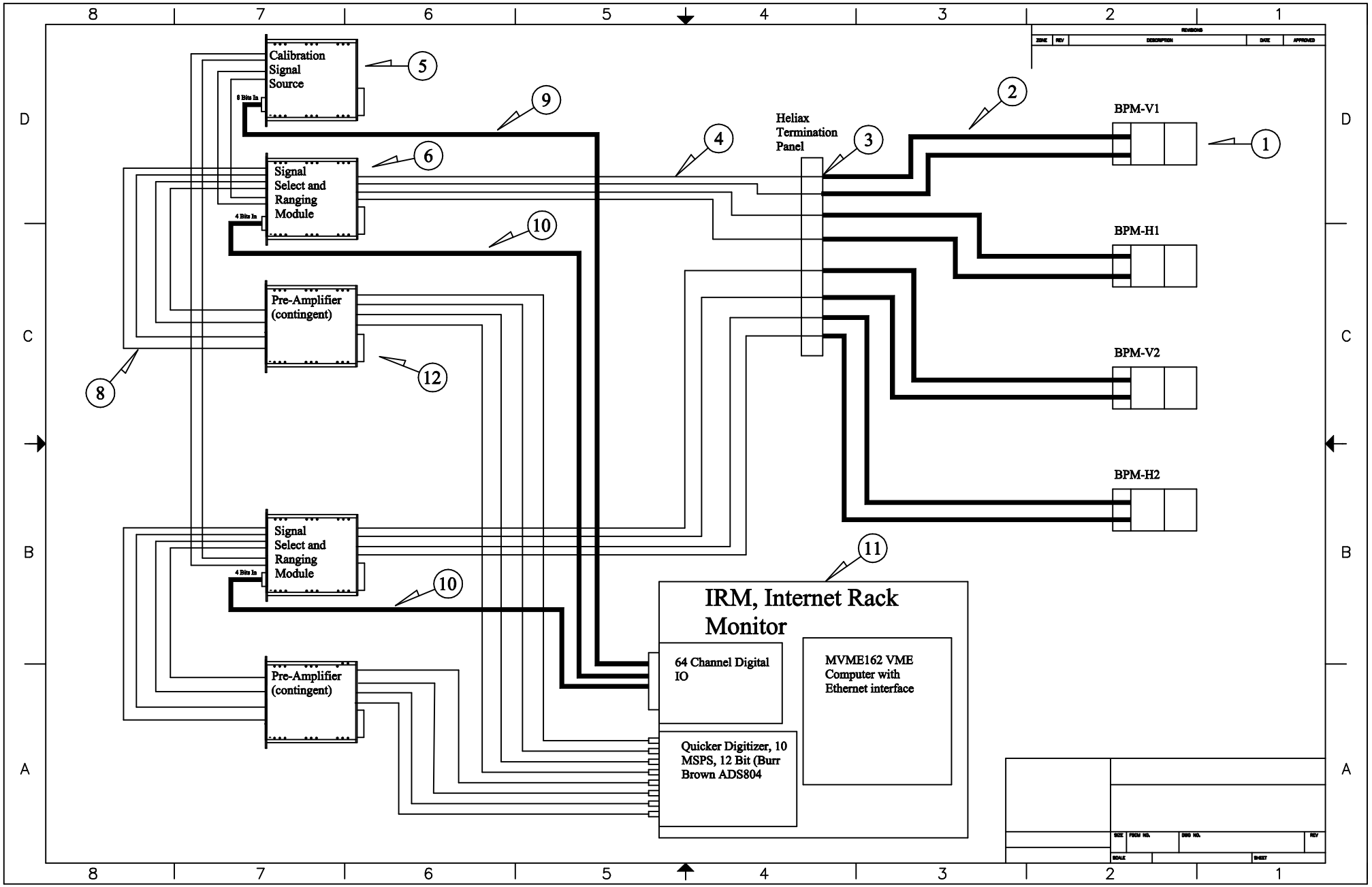
Calibration Signal Source
8 Bits In
Signal Select and Ranging Module
4 Bits In
Pre-Amplifier (contingent)
Signal Select and Ranging Module
4 Bits In
Pre-Amplifier (contingent)
Heliax Termination Panel
BPM-V1
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